SURFACE CHARACTERISATION OF CIRCULAR AND RIBBON SHAPED CARBON FIBERS

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1. INTRODUCTION

A series of recent studies has shown that the fragmentation technique can be successfully used to determine the interfacial characteristics of the model composites formed from pitch-based carbon fibers of circular cross-section and a polycarbonate matrix [1,2]. In the present work, this study is extended to monofilament composites with fibers of similar structure and mechanical properties, but with a different (ribbon shape) geometry.

2. EXPERIMENTAL

In this work pitch-based carbon fibers, P120J from Amoco and Ar-mesophase ribbon shaped carbon fibers produced at Clemson University [3], both unsized and untreated, were used. Their elasticity moduli were 830 GPa (from Amoco Product Information) and 850 GPa (from single filament tensile testing at a gauge length of 25 mm), respectively. The cross-section of the Ar-mesophase fibers, henceforth called ribbon fibers, was examined by optical microscopy. The average area, A, was determined to be 320 μm^2, and the aspect ratio (ratio of the width to thickness of the cross-section) was 3.2. The tensile strength of the fibers was assessed by tensile testing single filaments at four different gauge lengths (g.l.). The fibers' surface was analysed by scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS). The XPS measurements were conducted on a ESCALAB 200A-VG Scientific, with a Mg/Al double X-ray source and a vacuum limit of 10^{-8} Pa. Monofilament composites of the fibers under study and a polycarbonate matrix were prepared by compression moulding. Fragmentation tests were performed by tensile testing these composite samples, using a Instron 4505 machine, at a speed of 0.5 mm/min.

3. RESULTS AND DISCUSSION

a) Fiber Characterisation

The global atomic percentage of oxygen, as determined by XPS, was 2.7% for the P120J and 3.2% for the ribbon fibers, indicating a similar surface oxygen content for both types of fiber.

The tensile testing results for the monofilaments were obtained by performing approximately 40 single filament tests at four different gauge lengths. Then, the average tensile strength (σ) was determined at each gauge length. After correcting for machine compliance, the average modulus also was estimated. Assuming that single filament data can be modelled by a simple Weibull distribution, a linear variation of the logarithm of average tensile strength (σ) with gauge length (g.l.) would be expected [1,4]. Figure I shows this predicted variation of the σ with g.l..

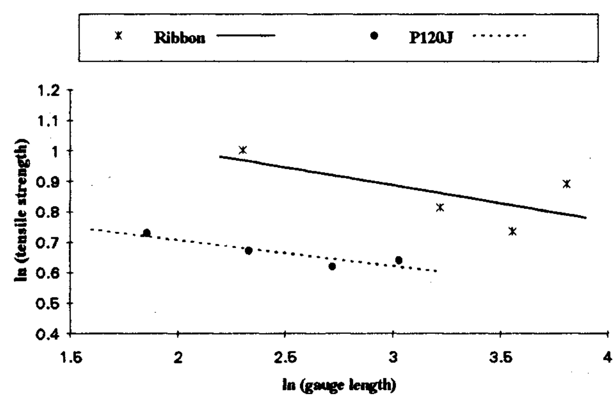

Figure I. ln (σ) vs. ln (g.l.) for the P120J (circular) and ribbon fibers.

A linear regression fit of the experimental results for the P120J fibers gives:

$$\ln\sigma = -\frac{1}{11.57}\ln(\text{g.l.}) + 0.88 \qquad (1)$$

Whereas, a linear regression fit of the ribbon fiber data gives:

$$\ln\sigma = -\frac{1}{8.41}\ln(g.l.) + 1.24 \qquad (2)$$

This provides a practical way of estimating the tensile strength for any gauge length.

b) Fragmentation Tests

After performing the tensile tests of the monofilament composites, the critical fiber length, l_c, was determined as described in [1]. For the circular fibers, the interfacial shear strength, τ_c, was calculated according to the Fraser-Di Benedetto model [5,6]:

$$\tau_c = \frac{d}{2l_c}\sigma(l_c) \qquad (3)$$

Where d is the average diameter of the fibers (9.6± 1μm) and $\sigma(l_c)$ is the tensile strength at a g.l. equal to l_c. For the ribbon shaped fibers, the model was generalised to any geometry and τ_r was calculated as:

$$\tau_r = \frac{2A}{Pl_c}\sigma(l_c) \qquad (4)$$

Where A and P are the area and perimeter of the fiber's cross-section. P was approximated as the perimeter of an ellipse whose major and minor axes satisfy the measured aspect ratio of the ribbon fibers, a/b=3.2 . The results obtained are presented in Table I.

Table I. Interfacial shear strength results from the fragmentation test.

Sample	l_c (μm)	τ (MPa)
P120J	1353	8.3
Ribbon	897	32.0

Past work has shown that the P120J and the ribbon fibers have similar electrical resistivities and mechanical properties [3]. The results of the present work, namely the mechanical characteristics (modulus and tensile strength) and the surface characteristics (morphology and oxygen content) confirm this point of view. Therefore, one might also expect the stress transfer properties of composites prepared at the same conditions to be similar. The fragmentation results, however, indicate that the interfacial stress transfer capability, in terms of τ, of the ribbon fibers is considerably better than that of the round P120J fibers. Unless other structural factors, not analysed in this work, are affecting the results, it would appear that fiber geometry alone can significantly influence the interfacial shear strength. Thus, fiber shape would ultimately influence composite properties.

4. CONCLUSIONS

In the present work, the mechanical properties and surface characteristics of pitch-based carbon fibers with two different geometries were studied. The fragmentation technique showed that the interfacial shear strength of the ribbon shaped carbon fibers in a polycarbonate matrix is substantially greater than that of similar pitch-based fibers of circular geometry.

ACKNOWLEDGEMENTS

The authors are indebted to Dr. Michel Nardin, from the Centre de Recherches sur la Physico-Chimie des Surfaces Solides, Mulhouse, France, for his help on the fragmentation technique and the discussions concerning fiber geometry.

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